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EXPERIENCE GAINED FROM PHOTOMETRIC STUDIES OF THE ATMOSPHERIC ACTIVITY OF JUPITER IN 1964-1965

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ABSTRACT. Regular observations of Jupiter were made at the Astrophysics Institute of the Academy of Sciences of the Kazak SSR in 1964-1965 in order to study short-term changes in Jovian atmospheric activity. The photometric activity factors of the northern and southern hemispheres of the planet are analyzed with respect to periodicity, amplitude and significance for additional investigation.

The solution of many problems of planetary physics, in particular problems /7* of the structure and the dynamics of planetary atmospheres, is not possible without a study of variable processes and phenomena occurring within these atmospheres. Such processes are observed not only in the atmospheres of the planets of the Earth group, which are comparatively close to the sun, but also on the giant planets which receive a relatively small quantity of energy from the sun and which display very low temperatures in the outer atmospheric layers and in the cloud cover. Particularly intensive processes are observed on Jupiter, notwithstanding the fact that the influx of solar energy on this planet is approximately 27 times less than that received by the Earth.

Our information concerning processes in the atmosphere of Jupiter is limited at the present time to data concerning changes which occur on the visible surface of the cloud layer of this planet. Radio-astronomical observation data at the present time do not reveal any noticeable association with optical phenomena. Although Jupiter has already been observed visually for several hundreds of years, sufficiently definite regularities in the active processes on Jupiter have not yet been established, if we do not consider the zonal nature detected in the rotation of the planetary cloud layer, confirmed by numerous visual, photographic and spectral measurements.

*Numbers in the margin indicate pagination in the foreign text.

It is true that in addition to the individual coordinates of several details on the planetary surface and the periods of their rotation, visual observations make it possible to study the development of various formations in the cloud layer, including bright spots, dark coagulations, outbursts of matter and other phenomena which indicate large-scale turbulent processes in the Jovian atmosphere. However, due to the inevitable subjectiveness in evaluations of visual observations, including even those furnished by qualified investigators, serious obstacles are encountered in connection with the use of these observations for the development of theories pertaining to such circulating processes on Jupiter.

It should be noted that numerous photographic observations of Jupiter, made in many world observatories, have been accomplished irregularly and the study of variable processes on the planet was apparently not established as their special purpose. Recently, attempts have been made to obtain measurement data on Jupiter in the form of quantitative rather that qualitative characteristics on the basis of available photographic observational material.

In 1953 R. Shapiro [1] studied from photographs of the Lowell Observatory changes in the relative intensity of all cloud belts of Jupiter in blue and yellow light during the period from 1926 to 1950 and detected a correlation /8 with solar activity. In 1964 Focas and Banos proposed to introduce as a quantitative characteristic of the state of the Jovian cloud layer the so-called photometric activity factor and they examined changes in its magnitude from 1952 to 1963. M. F. Khodyachikh [3] defined, from photographs of the Khar'kov Observatory, as an activity parameter the value of the average contrast of details on the Jovian disk and, for the period from 1932 to 1959, found a correlation between this parameter and the heliocentric distance of Jupiter and a lack of correlation with solar activity.

A shortcoming of all the works mentioned is the fact that the average annual characteristics of the state of the cloud layer of Jupiter were derived not on the basis of a series of photographs for an entire season of observations in a given year, but according to a limited number of photographs obtained at random. Of course, in this connection changes which occurred on Jupiter during the course of a season of its appearance could not be taken

into consideration. It cannot be excluded that changes of a short-range nature may be no less significant in magnitude than changes from year to year and therefore, the activity parameter obtained in accordance with a small quantity of observation dates may not correspond to the real average annual parameter. In themselves, short-term changes in the macroactivity of the Jovian atmosphere present no less interest than changes of greater duration, especially since the causes behind the changes may be different.

In this connection, in 1964-1965 regular photographic observations were undertaken as a first experiment at the observatory of the Astrophysics Institute of the AN Kazahk SSR [Academy of Sciences of the Kazakh SSR] with the purpose of the photometric study of short-term changes occurring on the visible surface of Jupiter. The results of these observations are set forth in the present article.

The Photometric Activity Factor

It was considered expedient to use the photometric activity factor introduced by Focas and Banos [2] as the parameter which characterizes the state of the visible surface of the cloud layer of Jupiter and which is sufficiently responsive to changes occurring in the optical properties of individual planetary regions. The application of any photometric parameters as an activity index for the atmosphere of Jupiter is based on the assumption that the quantity of dark matter on the visible surface of the cloud layer is determined by the intensity of the circulation processes in the atmosphere which facilitate either the release of this matter from deeper layers or its formation near the surface of the cloud layer due to a temperature change in specific cloud cover zones.

The photometric activity factor characterizes the relative quantity of dark matter in the equatorial and temperate belts of Jupiter. Determination of the factor is accomplished in the following manner. The photographic image of Jupiter is scanned photometrically along the central meridian. The photometric profile is constructed in relative intensity units $I(\phi)$, so that the light equatorial zone in the center of the disk corresponds to $I(0) = 1.0$. The latitude limits within which the photometric profile is constructed are $\pm 45°$.

The use of the intensity measurement at higher latitudes on the Jovian disk has no meaning since the accuracy of these measurements would be insufficient due to intensive darkening toward the poles. In using the graph $I(\phi)$ (see Figure 1), it is not difficult to define graphically the value /9

$$R = \frac{1}{S}\int_{-45^\circ}^{+45^\circ}[1-I(\varphi)]d\varphi, \qquad (1)$$

which is called the activity factor. In the formula S is the area of a rectangle limited by the segments $I(\phi) = 1$; $I(\phi) = 0$; $\psi = +45^\circ$; $\psi = -45^\circ$.

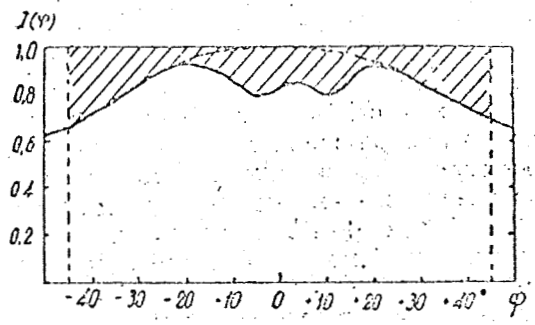

Figure 1. Method for the Graphical Determination of the Activity Factor.

It is clear that an increase in the quantity of dark matter on the Jovian disk causes an increase in the activity factor. Since darkening toward the edges of the disk already begins at latitudes less that 45°, even in the complete absence of dark matter the activity factor will not equal zero. If we accept the Lambert law (the cosine law) for the intensity distribution along the central meridian with no dark bands present, we may consider as a satisfactory approximation that for the latitudes ϕ 45° the activity factor

$$R_0 = \frac{1{,}571 - \int_{-45^\circ}^{+45^\circ}\cos\varphi\, d\varphi}{1{,}571} = 0{,}100. \qquad (2)$$

This must be kept in mind, not only in an examination of the results of our observations but also in connection with the use of data from the work of Focas and Banos.

Observation and Processing Technique

Photographic observations of Jupiter in 1964-1965 were made with the AZT-7 20-cm miniscus telescope with the aid of the MFN-3 microphoto adapter with ocular magnification. The equivalent focus of the entire optical system equalled 26.3 m and the scale of the image on the negative amounted to

7".8 in 1 mm. The linear diameter of the Jovian image during the period of observation changed within the limits 4.3-5.8 mm. Photography was accomplished on the RF-3 film through light filters, for which the effective wavelengths are shown in Table 1, with consideration for the spectral sensitivity of the film and the exposures are employed.

TABLE 1

Light Filter	λ_{eff} (mμ)	Exposure, sec.
KS-10	605	15-20
OS-12	585	3-5
ZS-1	532	10-15
SS-5	441	3-5
FS-7	405	7-10

Observations were made during the course of 73 nights from August 17, 1964 to March 10, 1965. Each night a series of photographs of Jupiter was made with all light filters -- 12 images with each filter. Approximately 4300 photographs were obtained. On these, 3 of the best images for each light /10 filter in an observation series for a given night were selected for further processing.

Calibration of the negatives was accomplished with the FSR-1 sensitometer; a photometric wedge was impressed upon each film with the KS-10 and SS-5 filters. As a rule, the development cycle was kept unchanged.

The photographs of Jupiter were measured photometrically on the MF-2 microphotometer along the central meridian through 0.1 mm. The photometric profiles were initially constructed in units of the logarithm of the intensity and then in relative intensities for the range of latitudes from - 45° to + 45°. Since the equatorial zone of Jupiter during the period of observations was not the brightest region of the disk, the zone was still occupied by a dark belt through which the light matter (see Figures 2 and 3) penetrated only in certain places. In order to determine the relative intensities, it was necessary to accomplish a reduction in the intensity of the light zones on the center of the disk, which was accomplished by the simple calculation log cos

ϕ_l from log I'_l of the light zone with latitude ϕ_l. The final intensity of individual points of the central meridian, with respect to the central reduced intensity I_0, was found from the formula

$$\log I(\phi) = \log I' - \log I'_0 = 10g\ I' - (\log I'_l - \log \cos \phi_l), \qquad (3)$$

where log I' is a value obtained from the characteristic curve from which the initial photometric profile was constructed.

In accordance with the $I(\phi)$ graph, the photometric activity factor R was then calculated in agreement with formula (1) and the values R_N and R_S were calculated for the northern and southern hemispheres separately.

If the photometric profiles of all three images measured agreed well with each other, subsequent processing (determination of R, R_N and R_S) was accomplished in accordance with the average profile. If the profiles differed somewhat, the activity factor was determined for each profile separately, and then the values obtained were averaged.

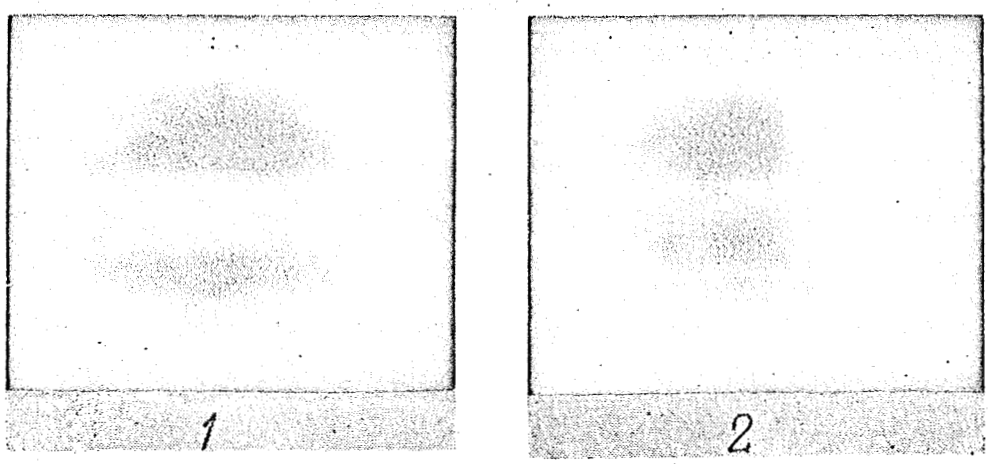

Figure 2. Photographs of Jupiter in Blue Light in 1962 (1) and in 1964 (2).

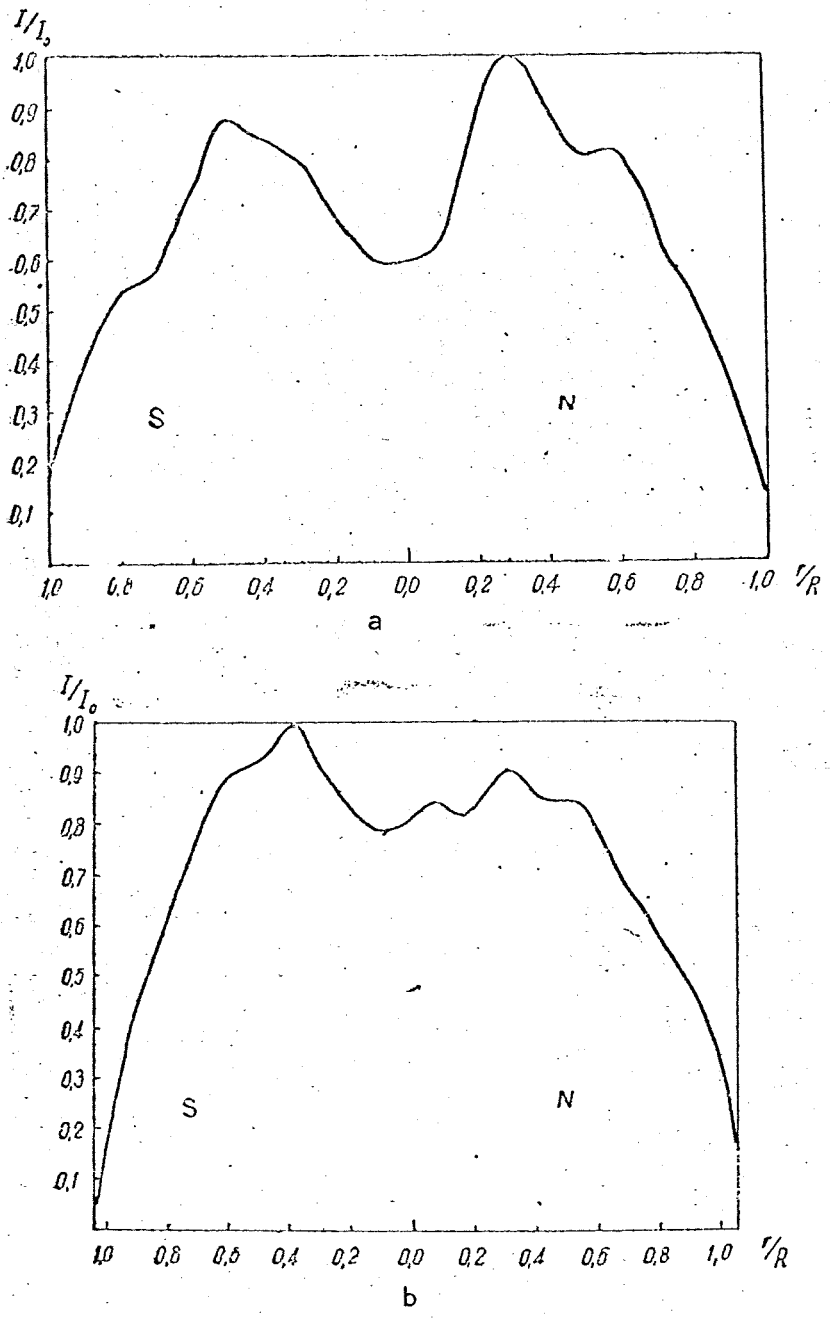

Figure 3. The Photometric Profile of the Jovian Disk along the Central Meridian in Blue Light: a, in 1962; b, in 1964.

Changes in the Activity Factor

The general course of changes on the Jovian disk in the 1964-1965 consisted of the gradual lightening of the equatorial region and an increase in the intensity of the North and South Tropical Zones. A comparatively narrow light zone, which intersected the broad dark belt, was visible on the equator of Jupiter in August, 1964 in orange light. In blue light this zone was very /12 noticeable and consisted of individual light spots. In December, 1964 the equatorial zone in orange light became broader and the dark North and South Equatorial Belts separated somewhat. On the equator this lightening was noted in daylight, but it was significantly less than in orange light. The North and South Temperate Belts became more intensive in comparison with the beginning of the season of observations. The south belt seemed darker in orange light and almost merged with the South Equatorial Belt. The North Tropical Zone, on the other hand, showed better visibility in blue light, whereas in orange light it was barely noticeable. This zone, as well as the Red Spot, appeared to be orange in color photographs of Jupiter obtained in December 1964 on AZT-8 70 cm telescope. The equatorial region was yellow and, south of the equator, passed the grayish-orange South Equatorial Belt, which is bordered on the south by the gray tropical zone. The North Equatorial Belt was gray, as were the polar regions and the South Temperate Belt, which, judging by photographs during this period, was in a state of maximum turbulence.

In 1964 in the South Temperate Belt, sharp differences in belt intensity by longitude were observed; in September the belt was almost unnoticeable in the region of longitudes from 90 to 220° (II system), whereas in the remaining part the belt was relatively well defined. In December of 1964 the eastern end of the belt already had a longitude of approximately 20°, rather than 90°, so that the belt was sharply attentuated near the Red Spot.

It is quite clear that on photometric segments of the Jovian disk along the central meridian, the brightness of the light zone in the southern hemisphere in the 15-30° range of latitudes in blue and violet light is significantly higher than the brightness of the light zone in the northern hemisphere (latitudes 10-25°). The brightness of both zones is almost identical in green,

orange and red light. The relative difference in intensities of the segments, with maximum brightness in southern and northern hemispheres in different colors, is shown in Table 2, where $J = \frac{I_S}{I_N}$.

In the northern hemisphere of Jupiter there is more dark matter than in the southern hemisphere, and in addition, it is possible that the light matter of the northern zone has a more reddish coloration. As a result, it seems less bright in blue and violet light.

TABLE 2

Filter	J Limits
KS-10	0.89-1.07
OS-12	0.89-1.07
ZS-1	0.87-1.12
SS-5	1.07-1.26
FS-7	1.12-1.42

Activity factor values obtained after photometric processing of the photographs of Jupiter for each night of observations are shown in Table 3, while the limits of changes across the entire disk are shown in Table 4.

TABLE 4

Filter	R Limits
KS-10	0.115-0.215
OS-12	0.118-0.246
ZS-1	0.109-0.250
SS-5	0.182-0.328
FS-7	0.203-0.419

The dependence of the activity factor average values $\overline{R}$ on wavelength during the entire season of observations is shown in Figure 4. Maximum activity factor values are obtained in blue and violet light and minimum values are obtained in orange and red light. In this connection the difference in values $\overline{R}$ for green, orange and red filters proves to be insignificant, just as is the difference between $\overline{R}$ in blue and violet light.

The overall behavior of changes in the activity factor during the course of the entire period of observations from August, 1964 to March, 1965 is shown

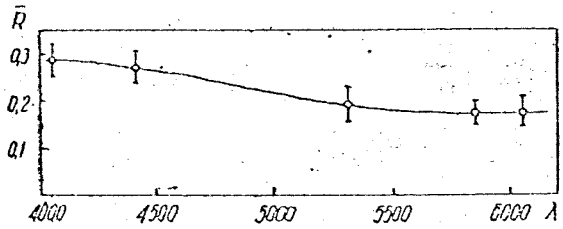

Figure 4. The Average Value of the Activity Factor as a Function of Wavelength.

in Figure 5. It is not difficult to see that in all filters, values $\overline{R}$ experience rather sharp fluctuations. As will be seen from subsequent analysis, these fluctuations are apparently caused mainly by measurment errors. However, the regularity defined in the general behavior of the activity factor draws attention; individual fluctuations are superimposed on a certain periodical change in the activity factor. The periodicity is most clearly expressed in graphs for red, orange and green light. The period of the changes appears to equal approximately 3 months. Maximum activity factor values occur at the end of August and the beginning of September, 1964 and at the end of November, 1964. Minimal activity was noted in mid-October, 1964 and at the beginning of January, 1965. Observations in 1965 were fewer and therefore it is more difficult to judge the nature of the activity factor at the beginning of 1965, although everything gives the impression that toward the end of the season of the appearance of Jupiter, its activity became less; the amplitude of fluctuations in various R became noticeably less. Periodicity in changes in the activity factor in blue and violet light practically does not appear.

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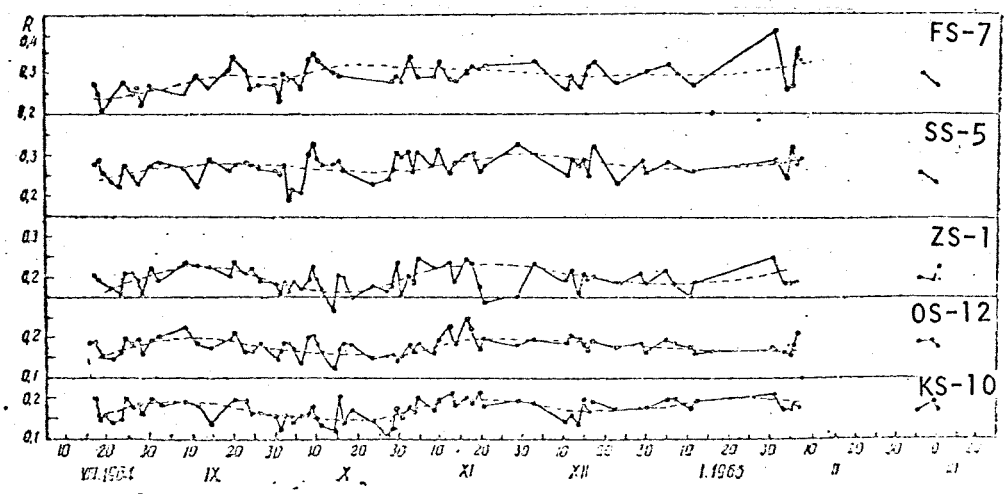

Figure 5. Changes in the Activity Factor of Jupiter across the Entire Disk In Different Colors in 1964-1965.

TABLE 3

Number	Date	FS-7			SS-5			ZS-1			OS-12			KS-10		
		R_s	R_n	R	R_s	R_n	R	R_s	R_n	R	R_s	R_n	R	R_s	R_n	R
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1	17—18. 08.64	0,234	0,316	0,274	0,236	0,320	0,279	0,178	0,218	0,198	0,163	0,214	0,189	0,210	0,200	0,205
2	18—19. 08.64	0,204	0,290	0,246	0,254	0,316	0,283	0,172	0,204	0,188	—	—	—	0,151	0,146	0,149
3	19—20. 08.64	0,160	0,238	0,203	0,209	0,295	0,251	—	—	—	0,132	0,180	0,150	0,152	0,168	0,159
4	21—22. 08.64	0,189	0,280	0,231	0,206	0,259	0,233	0,205	0,140	0,172	0,128	0,170	0,147	0,138	0,147	0,143
5	23—24. 08.64	—	—	—	0,187	0,259	0,223	0,150	0,161	0,156	0,159	0,162	0,161	0,148	0,151	0,148
6	24—25. 08.64	0,226	0,333	0,279	0,230	0,322	0,276	0,208	0,210	0,209	0,162	0,239	0,200	0,178	0,230	0,204
7	26—27. 08.64	0,191	0,301	0,246	0,205	0,289	0,247	0,204	0,211	0,207	0,179	0,193	0,186	0,176	0,193	0,182
8	27—28. 08.64	0,209	0,310	0,260	0,206	0,248	0,227	0,177	0,202	0,190	0,186	0,208	0,197	0,144	0,232	0,188
9	28—29. 08.64	0,197	0,241	0,219	—	—	—	0,129	0,178	0,154	0,149	0,160	0,155	0,151	0,168	0,160
10	30—31. 08.64	0,214	0,326	0,270	0,229	0,320	0,274	0,219	0,224	0,221	0,152	0,231	0,191	0,208	0,196	0,202
11	2— 3. 09.64	—	—	—	0,217	0,347	0,282	0,150	0,222	0,186	0,169	0,236	0,203	0,157	0,218	0,187
12	8— 9. 09.64	0,175	0,320	0,247	0,228	0,310	0,269	0,186	0,279	0,233	0,172	0,282	0,227	0,165	0,219	0,192
13	11—12. 09.64	0,230	0,348	0,289	0,203	0,238	0,220	0,198	0,261	0,227	0,162	0,208	0,185	0,174	0,201	0,187
14	14—15. 09.64	0 246	0,274	0,260	0,255	0,322	0,288	0,197	0,250	0,224	0,166	0,182	0,174	0,144	0,131	0,137
15	19—20. 09.64	0,242	0,363	0,302	0,206	0,320	0,263	0,155	0,246	0,200	0,181	0,207	0,194	—	—	—
16	20—21. 09.64	0 286	0,390	0,338	0,238	0,309	0,274	0,186	0,285	0,235	0,170	0,257	0,214	0,156	0,238	0,197
17	23—24. 09.64	0,251	0,358	0 304	0,215	0,345	0,280	0,159	0,254	0,207	0,143	0,186	0,164	0,140	0,243	0,191
18	24—25. 09.64	0,222	0,298	0,256	0,245	0,305	0,275	0,207	0,230	0,210	0,166	0,163	0,164	0,161	0,159	0,160
19	26—27. 09.64	0,214	0,313	0,268	0,238	0,295	0,265	0,182	0,193	0,187	0 169	0,206	0,187	0,170	0,160	0,165
20	30—09.1.10.64	0,220	0,326	0,269	0,225	0,288	0,257	0,160	0,196	0,183	0,130	0,156	0,141	0,145	0,167	0,156
21	1— 2. 10.64	0,186	0,256	0,224	0,198	0,285	0,249	0,160	0,149	0,155	0,158	0,173	0,166	0,136	0,108	0,120
22	2— 3. 10.64	0,254	0,352	0,296	0,229	0,325	0,275	0,185	0,189	0,187	0,180	0,193	0,185	0,159	0,161	0,160
23	3— 4. 10.64	0,230	0,326	0,280	0,176	0,196	0,182	0,145	0,164	0,156	0,167	0,206	0,186	0,162	0,148	0,156
24	4— 5. 10.64	0,234	0 341	0,287	0,181	0,250	0,214	0,163	0,220	0,190	0,164	0,194	0,170	0,163	0,139	0,142
25	6— 7. 10.64	0.222	0,303	0,258	0,198	0,226	0,202	0,170	0,162	0,164	0,152	0,124	0,132	0,164	0,152	0,158
26	8— 9. 10.64	0 286	0,401	0 342	0,297	0,309	0,301	0,207	0,169	0,188	0,200	0,202	0,193	0,147	0,179	0,162
27	9—10. 10.64	0,296	0,437	0,354	0,283	0,401	0,328	0,198	0,284	0,229	0,199	0,243	0,204	0,175	0,203	0,178
28	10—11. 10.64	0,270	0,394	0,328	0,256	0,354	0,290	0,194	0,229	0,193	0,171	0,221	0,181	0,180	0,173	0,147
29	11—12. 10.64	—	—	—	0,245	0,305	0,275	0,170	0,173	0,170	0,143	0,179	0,161	0,135	0,130	0,132
30	14—15. 10.64	0,256	0,363	0,300	0,238	0,315	0,276	0,147	0,080	0,109	0,145	0,091	0,118	0,127	0,102	0,115
31	15—16. 10.64	0,258	0,367	0,296	0,257	0,319	0,283	0,212	0,195	0,204	0,177	0,162	0,169	0,218	0,189	0,203
32	16—17. 10.64	—	—	—	0,272	0,238	0,260	0,231	0,183	0,199	0,193	0,200	0,185	0,171	0,111	0,134
33	18—19. 10.64	—	—	—	—	—	—	0,155	0,184	0,146	0,176	0,191	0,181	0,173	0,169	0,170

Tr. Note: Commas indicate decimal points.

TABLE 3 (continued)

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
34	23—24. 10.64	—	—	—	0,210	0,263	0,226	0,177	0,214	0,176	0,145	0,159	0,145	0,153	0,136	0,141
35	27—28. 10.64	—	—	—	0,206	0,286	0,238	0,173	0,186	0,161	0,150	0,152	0,151	0,133	0,076	0,106
36	28—29. 10.64	0,230	0,333	0,262	0,220	0,316	0,260	0,164	0,220	0,178	0,162	0,161	0,155	0,137	0,135	0,122
37	29—30. 10.64	0,253	0,368	0,292	0,272	0,362	0,305	0,222	0,258	0,236	0,162	0,153	0,141	0,149	0,196	0,173
38	30—31. 10.64	0,246	0,306	0,276	0,234	0,356	0,295	0,184	0,154	0,146	0,128	0,172	0,150	0,149	0,152	0,150
39	2— 3. 11.64	0,263	0,417	0,340	0,254	0,378	0,308	0,200	0,240	0,205	0,167	0,234	0,180	0,176	0,183	0,179
40	3— 4. 11.64	—	—	—	0,227	0,315	0,255	0,156	0,212	0,180	0,165	0,157	0,161	0,163	0,164	0,155
41	4— 5. 11.64	0,241	0,342	0,288	0,283	0,361	0,308	0,216	0,277	0,246	0,179	0,216	0,185	0,177	0,206	0,198
42	8— 9. 11,64	0,255	0,342	0,290	0,254	0,304	0,271	0,206	0,224	0,222	0,135	0,197	0,152	0,141	0,163	0,165
43	9—10. 11.64	0,291	0,389	0,326	0,270	0,395	0,312	0,199	0,261	0,218	0,168	0,218	0,190	0,176	0,218	0,191
44	12—13. 11.64	0,218	0,343	0,282	0,210	0,295	0,250	0,211	0,293	0,236	0,193	0,287	0,228	0,177	0,250	0,214
45	13—14. 11.64	0,216	0,345	0,278	0,228	0,336	0,279	0,160	0,216	0,177	0,172	0,200	0,177	0,160	0,200	0,180
46	16—17. 11.64	0,220	0,377	0,298	0,247	0,367	0,298	0,211	0,295	0,242	0,184	0,266	0,246	0,147	0,233	0,195
47	17—18. 11.64	0,268	0,389	0,314	0,262	0,379	0,302	0,213	0,260	0,235	0,199	0,261	0,224	0,193	0,177	0,188
48	19—20. 11.64	0,264	0,358	0,310	0,229	0,294	0,256	0,182	0,180	0,175	0,154	0,184	0,169	0,211	0,220	0,215
49	20—21. 11.64	0,258	0,376	0,317	0,238	0,347	0,273	0,132	0,156	0,133	0,191	0,226	0,195	0,173	0,170	0,171
50	28—29. 11.64	—	—	—	0,285	0 359	0,325	0,155	0,145	0,150	0,185	0,181	0,182	0,206	0,174	0,190
51	2— 3. 12.64	0,265	0,395	0,330	0,253	0,350	0,301	0,212	0,259	0,235	0,177	0,216	0,195	0,188	0,186	0,187
52	10—11. 12.64	0,225	0,292	0,259	0,227	0,271	0,249	0,181	0,199	0,190	0,178	0,191	0,186	0,136	0,148	0,242
53	11—12. 12.64	0,239	0,341	0,291	0,245	0,325	0,287	0,195	0,233	0,216	0,198	0,211	0,206	0,146	0,171	0,159
54	13—14. 12.64	0,250	0,352	0,301	0,233	0,309	0,272	0,200	0,245	0,222	0,144	0,181	0,162	0,135	0,160	0,147
55	14—15. 12.64	0,254	0,347	0,292	0,243	0,333	0,288	0,181	0,232	0,206	0,166	0,209	0,183	0,193	0,194	0,194
56	15—16. 12.64	0,273	0,358	0,315	0,208	0,273	0,243	0,186	0,211	0,196	0,153	0,177	0,165	0,173	0,156	0,165
57	16—17. 12.64	0,263	0,377	0,328	0,305	0,353	0,324	0,191	0,208	0,199	0,179	0,209	0,194	0,185	0,193	0,192
58	22—23. 12.64	0,219	0,332	0,276	0,199	0,249	0,226	0,169	0,202	0,185	0,177	0,173	0,175	0,157	0,186	0,171
59	28—29. 12.64	—	—	—	0,236	0,329	0,283	0,182	0,232	0,208	0,166	0,206	0,186	0,170	0,182	0,176
60	29—30. 12.64	0,262	0,347	0,302	0,229	0,287	0,256	0,169	0,197	0,184	0,150	0,175	0,162	0,158	0,134	0,171
61	4— 5. 01.65	0,281	0,360	0,321	0,249	0,313	0,281	0,189	0,251	0,220	0,177	0,207	0,192	0,174	0,212	0,194
62	6— 7. 01.65	—	—	—	—	—	—	0,149	0,205	0,178	0,178	0,185	0,182	0,186	0,203	0,195
63	10—11. 01.65	0,171	0,337	0,270	0,229	0,296	0,261	0,133	0,171	0,153	0,164	0,184	0,174	0,158	0,187	0,174
64	11—12. 01.65	—	—	—	—	—	—	0,203	0,171	0,187	0,168	0,155	0,161	0,197	0,185	0,191
65	30—31. 01.65	0,348	0,470	0,409	0,243	0,337	0,290	0,220	0,279	0,250	0,158	0,189	0,174	0,170	0,241	0,206
66	3— 4. 02.65	0,209	0,316	0,264	0,209	0,276	0,244	0,172	0,195	0,183	0,166	0,165	0,165	0,166	0,172	0,169
67	4— 5. 02.65	0,232	0,322	0,270	0,261	0,386	0,324	0,174	0,201	0,187	0,148	0,171	0,157	0,169	0,169	0,169
68	5— 6. 02.65	0,230	0,293	0,260	0,218	0,329	0,273	0,160	0,211	0,187	0,157	0,187	0,179	0,174	0,192	0,183
69	6— 7. 02.65	0,261	0,408	0,335	0,248	0,320	0,290	—	—	—	0,206	0,214	0,211	0,172	0,181	0,176
70	5— 6. 03.65	0,248	0,366	0,307	0,216	0,303	0,260	0,168	0,220	0,194	0,166	0,213	0,189	0,145	0,189	0,167
71	9—10. 03.65	0,223	0,321	0,273	0,186	0,276	0,231	0,175	0,206	0,191	0,175	0,200	0,189	0,183	0,200	0,191
72	10—11. 03.65	—	—	—	—	—	—	0,178	0,240	0,229	0,155	0,199	0,177	0,156	0,184	0,170

Similar graphs of the change in the activity factor are plotted separately for the northern and southern hemispheres (see Figure 6). These graphs show the sharply expressed difference in the degree of activity of the two hemispheres of Jupiter. While in the southern hemisphere the activity factor shows comparatively little change and reveals no periodicity in changes, in the northern the picture is completely different. The activity factor in red, orange and green light fluctuates from night to night very intensively, but /16 the main point is that the periodic nature of this fluctuation appears clearly, specifically, in the northern hemisphere. The maximum amplitude of changes in R are observed in green light. In blue and violet light neither the northern nor the southern hemisphere reveal sufficiently clear periodicity (in blue light the northern hemisphere still reveals a certain periodicity, but it is superimposed on the general increase in the activity factor toward the end of November, 1964). In violet light only a general increase in the activity factor was observed from August to the beginning of December, 1964, and then a small drop occurred. A certain gradual increase in the activity factor also occurred in the southern hemisphere.

It was noted above that the North Equatorial Belt is more active than the South. Here numerous spots and vortices are observed, especially at the edges of the belt, which indicate rather powerful turbulent phenomena at this belt of the Jovian atmosphere. Observed characteristics in activity factor changes confirm the existence of sharply expressed active processes, particularly in the North Equatorial Belt, which mainly result from the observational picture of changes occurring in the photometric properties of the Jovian disk during the 1964-1965 season.

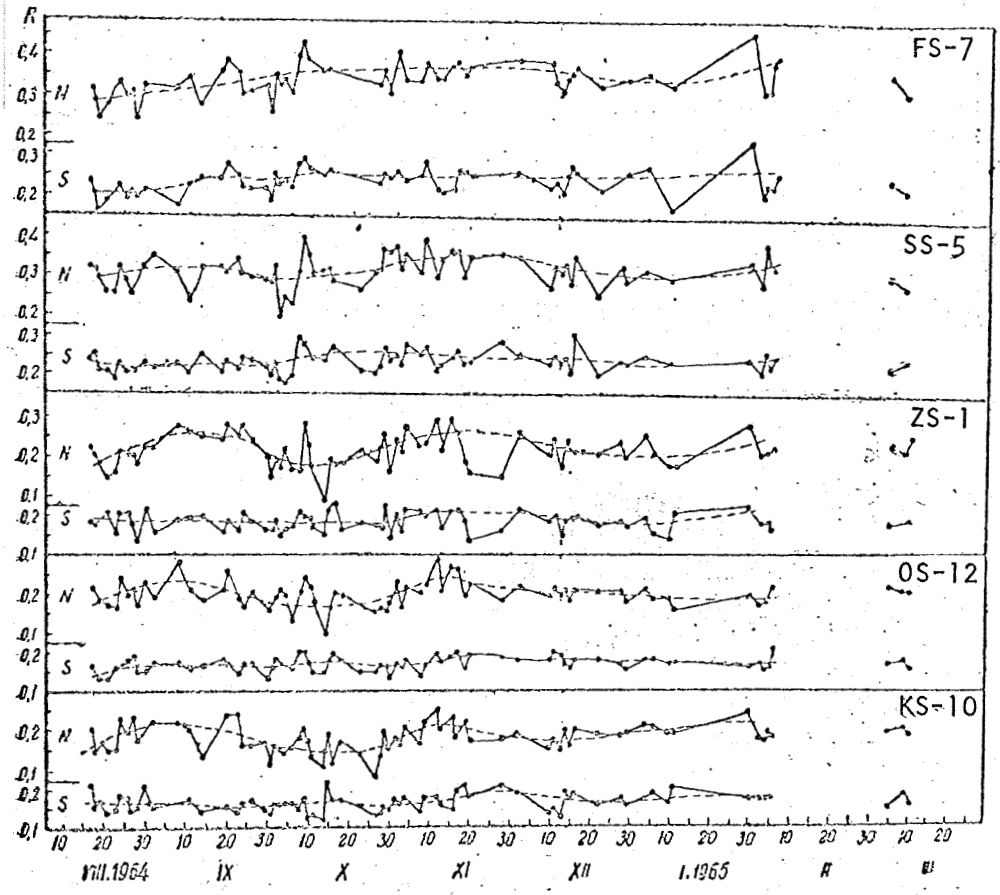

Figure 6. Changes in the Activity Factor in the Northern and Southern Hemispheres of Jupiter in Different Colors in 1964-1965.

Strictly speaking, the fluctuations in the activity factor values themselves must be examined as a characteristic of the intensity of the atmospheric circulation on Jupiter. As shown in Figure 7, where changes in the activity factor are shown for the period 1953-1965 (prior to 1964, according to data by Focas and Banos). For a number of years the activity factor varied below 0.050 (from 1955 to 1962). Short-term changes in the activity factor occurred in 1964 within these limits, or even somewhat greater ones. Therefore, the activity of the Jovian atmosphere must be characterized first of all by a rate /17

and amplitude of changes in optical parameters of the cloud cover of the planet during the course of the given season of the appearance of Jupiter. It is possible to do this only in connection with systematic photographic or photoelectric observations of the planet, accomplished if possible on every clear night.

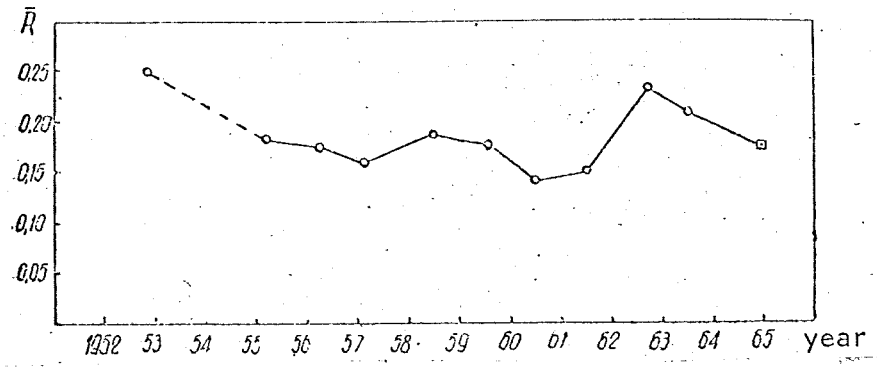

Figure 7. Behavior of the Activity Factor in Yellow Light by Year. The Small circles represent data by Focas and Banos. The small squares represent observations in 1964-1965 at the Astrophysics Institute of the Academy of Sciences of the Kazh SSR.

A Preliminary Analysis of the Results of Observations

First of all we shall examine changes in the activity factor which are common for the entire disk. As seen from Figure 5, fluctuations in values R will all filters occurred in an extremely irregular fashion and with rather high amplitudes of individual fluctuations. If these fluctuations are caused by real changes in the intensity of dark belts on the disk, then we could anticipate a rather high correlation between values R for adjacent segments of the spectrum. However, such a correlation is practically lacking--correlation coefficients r_ϕ do not exceed 0.5: in comparing data obtained with the filters FS-SS, SS-ZS, ZS-OS and FS-KS, we obtain r_ϕ values + 0.46; + 0.33; + 0.35; and + 0.35, respectively.

Generally, the distribution of deviations of R values from the average prove to be close to normal. Normal distribution is satisfied in a better manner by deviations from the sinusoid-resembling curves of the overall behavior of the activity factor represented in Figure 5 by a dashed line. Appar-

ently, separate values R are aggravated by measurement errors which more than likely are associated not with errors in the photometric measurement of photographic images of Jupiter, but rather with measurement reduction. The fact /18 is that the reduction accomplished in the intensity of light zones on the center of the Jovian disk, required in order to calculate the activity factor, depends on the extent to which the brightness of the light zones remain constant. If the light zones themselves vary their color and brightness, then with the same dark belt intensity the activity factor values will vary due to inconstancy of the zero-point of reference of relative intensities. Of course, the quality of the photographic image of the planet must also effect the activity factor values. The quality probably does not play a significant role since only the best images were selected for measurements. However, this cause cannot be completely excluded.

In irregular R fluctuations, a longitude effect may appear if the quantity of dark matter (the width and intensity of the belt) varies with longitude. However, a comparison of values R with longitudes in the I and II system revealed an almost complete lack of dependence on longitude. Avergae values $\overline{R}_d$ over a 60-degree longitudinal interval differ by not more than ± 0.015 and only in blue and violet light in the II system, did one region with L_{II} = 0 to 60° reveal deviations $\overline{R}_d$ by 0.055 of the maximum value. However, this longitudinal interval corresponds to a lower number of observations than other intervals.

The difference in the degree of activity in the northern and southern hemispheres of Jupiter presents particular interest. Graphs were constructed of the change in level values $\overline{R}$, calculated as sliding means from 6 neighboring activity factor values and graphs of the behavior of average values R_{10}, calculated in ten-day intervals (see Figure 8). Both definitely indicate the existence of significantly greater changes in the quantity of dark matter in the northern hemisphere in comparison to the southern. Although the periodic nature of the general behavior of the activity factor in the northern hemisphere stands out, according to the ten-day averages, most clearly only in green light, the difference in hemispheric activity can cause no doubts. The activity factor in the southern hemisphere shown practically no variance with

time, whereas in the northern hemisphere its behavior in red, yellow and green light proves to be completely different.

On the other hand, in blue and violet light hte difference between hemispheres is smoothed over. This is also reflected in the values of the activity factor correlation coefficients between the northern and southern hemispheres: for FS-7, SS-5, ZS-1, OS-12, KS-10 filters the correlation coefficients r_{NS} equal + 0.80; + 0.60; + 0.46; + 0.48; and + 0.68, respectively.

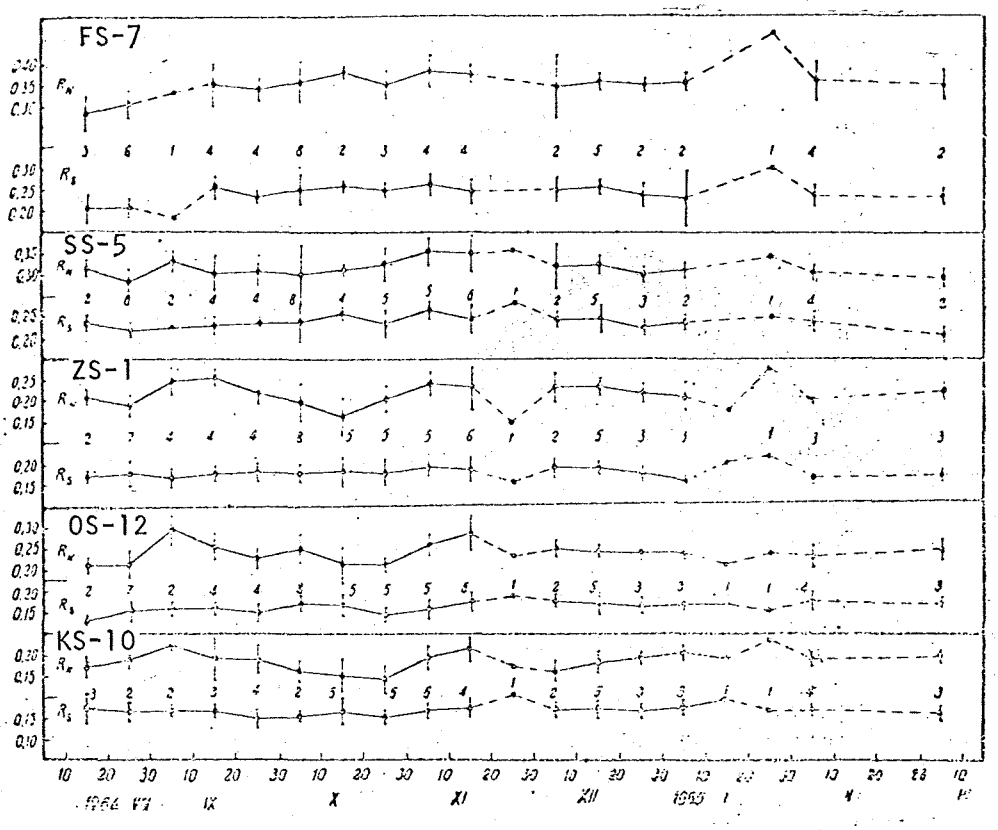

Figure 8. Average Values of the Activity Factor in Different Colors for the Northern and Southern Hemispheres of Jupiter, Calculated According to Ten-Day Intervals. The numbers near the points indicate the total number of observation nights in each interval.

The high correlation coefficient between hemispheres is obtained only in violet light, where there are no hints of periodicity in the behavior of the activity factor.

The peculiarity in observed changes on the Jovian disk, i.e., the clearly expressed difference in the degree of hemispheric activity according to photo-

graphs in red, orange and green light and the lack of this difference in blue and particularly in violet light, in our view, may be explained as follows. In 1964-1965, the equatorial region of Jupiter was covered by an orange haze, situated between the gray or blueish north and south belts. This haze was clearly visible on the color photographs of Jupiter obtained and was also noted during visual observations. It is apparently transparent in long-wave light, since on photographs made through red, orange and green filters the equatorial region was registered clearly. In this connection the dark matter of the North and South Equatorial Belts played a main role in the value of the activity factor. A change in the quantity or in the coloration of this matter in the North Equatorial Belt also defined activity factor fluctuations observed in the northern hemisphere.

The matter composing the orange haze, which may be situated at a great height above the cloud surface, played a definitive role in the magnitude of the activity factor in short-wave light. Being opague for violet and semi-opaque for blue light and being situated above the active zone of the cloud layer, the orange haze may not participate in short-term changes which occur in the North Equatorial Belt. As a result, although the value of the activity factor was maximum in blue and violet light, active processes in the North Equatorial Belt had practically no effect on activity factor changes.

The statement that the matter of the orange haze was situated above the main surface of the cloud layer requires proof. At the present time, we can point only to one phenomenon, quite noticeable on color and filter photographs of Jupiter, obtained in the fall of 1965, when the orange haze, having shifted to the north, partially covered the gray North Equatorial Belt. In places where vortex projections of this belt were situated, it was possible to see that the belt was not screened by the orange haze. The uneven southern boundary of the North Equatorial Belt was visible in red light. In blue light the photographs showed only the orange haze in the form of a dark band with a uniform southern edge. This means that the arrangement of the orange haze repeats neither the position nor the outline of the North Equatorial Belt, i.e., the haze is not subject to those active processes which are observed in the belt.

This may serve as a conclusion in favor of the assumption concerning the high altitude of the orange haze.

At the present time, it is not possible to say anything definite concerning the mechanism of the short-periodical changes detected in the atmosphere of Jupiter. As a result of subsequent investigations of atmospheric activity on Jupiter, it will be necessary to qualify which zone of the atmosphere, with respect to altitude, encompasses the changes observed. There are two versions possible here. If the source of the atmospheric activity is the release of internal planetary heat, then variable processes in the atmosphere must begin from below, from the base of the atmosphere and must encompass its entire thickness. Then we must see on the surface of the cloud layer only an attenuated reflection of more powerful internal processes. Recently, serious discussion has been given to the possibility of the action in the external layers of the Jovian atmosphere of the greenhouse effect [4, 5]. If ammonia and molecular hydrogen can create a noticeable greenhouse effect, its instability may lead to changes in the radiation cycle of the external atmosphere and of the upper part of the cloud layer, as a result of which, changes in the circulation processes of the Jovian atmosphere may occur. It is clear that the energy of the active processes on Jupiter will not be identical in both cases. In connection with a main role for the greenhouse effect, we may anticipate that active processes on Jupiter will be rather closely associated with solar activity.

We made an attempt to compare changes observed in the activity factor with solar and geomagnetic activity indices. During the period of observations of Jupiter, the overall solar activity level was very low. We selected data concerning solar activity in agreement with the difference in heliocentric longitudes of Jupiter and the Earth for an approximate moment.

$$T = T_0 + \frac{\Delta L}{\omega_\odot},$$

where

T_0 is the date of the observation of Jupiter;

$\Delta L = L_\odot - L_\varphi$, which is the difference in heliocentric longitudes;

$\omega_\odot = 13.3$ deg/day, the angular velocity of the rotation of the sun.

Correlation coefficients were calculated between the values of the activity factor in blue and orange light and the Wolf numbers. No correlation was found (r_{ob} = + 0.070; r_{ss} = - 0.138). No association was found between the activity factor and the area of spots or with geomagnetic disturbances.

Investigations of active processes in the Jovian atmosphere by photometric methods may of course furnish important information concerning regularities to which these processes are subordinate. Although the photographic method gives less resolution of details of the visible surface of Jupiter than visual observations, only photographic and electrophotometric observations permit us to use objective quantitative characteristics for observed phenomena. /21 The activity factor in the film introduced by Focas and Banos and employed in the present article is apparently not the best activity parameter. First, it is not the value R itself, but rather its change with time which really reflects the intensity of phenomena that occur on Jupiter. Secondly, a certain amount of uncertainty remains in connection with the reduction of intensities on the Jovian disk to the brightness of the light zone, which may undergo substantial fluctuations itself. Therefore, the activity factor may be reliably employed only in connection with absolute photometry of the Jovian disk, which seriously complicates the conduct of regular observations of Jupiter, since it is necessary each night to accomplish photometric tie-ins, to check atmospheric transparence, etc. It is more expedient, in our view, to develop a system of indices of the atmospheric activity of Jupiter which may be employed independently of absolute photometric measurements.

It is also completely clear that the fulfillment of a complete, regular photometric program of observations of Jupiter requires the participation of several observatories with approximately identical instruments. On the one hand, this may facilitate continuity in observations, and on the other hand, it may facilitate mutual control of the results obtained. Work of such nature was recently recommended by the Committee on International Cooperation in Planetary Observations of Commission Number 16 of the International Astronomical Union.

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